Possible Collaboration with the Energy Frontier Group

- The group currently
  - has 6 members
  - was funded by the Muon Accelerator Program studying Muon Colliders and Neutrino Factories
  - but this in now coming to an end
  - and we are looking for new projects
- We have expertise in:
  - Superconducting and pulsed magnets
  - Energy deposition studies
  - Radiation Damage Studies
  - Beam dynamics

Some accelerator issues for a 100 TeV pp collider

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(BNL)
Y. Alexahin (FNAL)
V. Litvinenko (SUNY)

These ideas have been developed in discussions with FCC and others and have, in earlier form, been reported to the HEPAP Accelerator R&D Pannel

1. Luminosity considerations
2. Synchrotron Radiation considerations

   And if of interest, I have added a discussion of:

3. Cost vs. bending fields

1) LUMINOSITY

$$\mathcal{L} \propto \frac{\gamma\ I}{\beta^*}\Delta\nu \qquad I \propto (f\ N_p) \qquad \Delta\nu \propto \left(\frac{N_p}{\epsilon_\perp}\right)$$

where f = bunch frequency, N_p = protons per bunch, $\epsilon_\perp$ = normalized rms transverse emittance, β^* = IP Courant-Snyder function, $\Delta\,\nu$ = beam-beam tune shift, and I = beam current

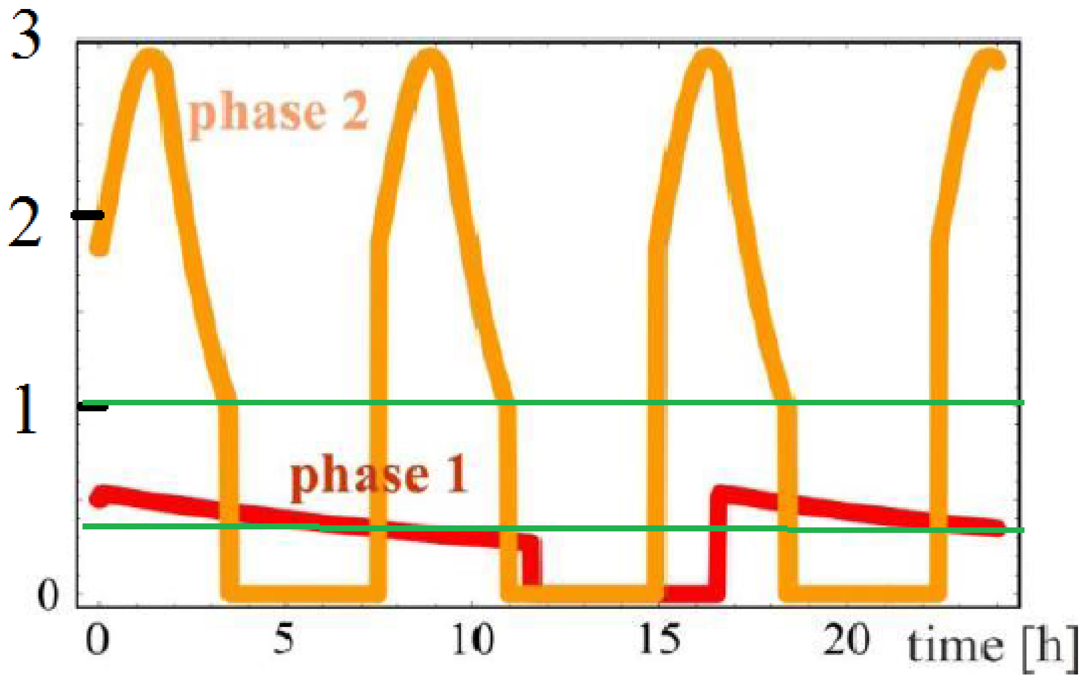
Fundamental cross sections fall with $1/\gamma^2$, so lumiosity should rise as γ^2. Going from LHC at 14 TeV to 100 TeV we need:

$$\mathcal{L}_{100} \geq 1\ 10^{34} \times \left(\frac{100}{14}\right)^2 = 5\ 10^{35} \quad (\mathrm{cm}^{-2}\mathrm{s}^{-1})$$

FCC Average Luminosities

Assuming I = 0.5 amp 100 TeV B = 16 T

Luminosities 10^{35} cm^{-2} s^{-1}



Averages

Phase 2 ~ 1.0
Phase 1 ~ 0.3

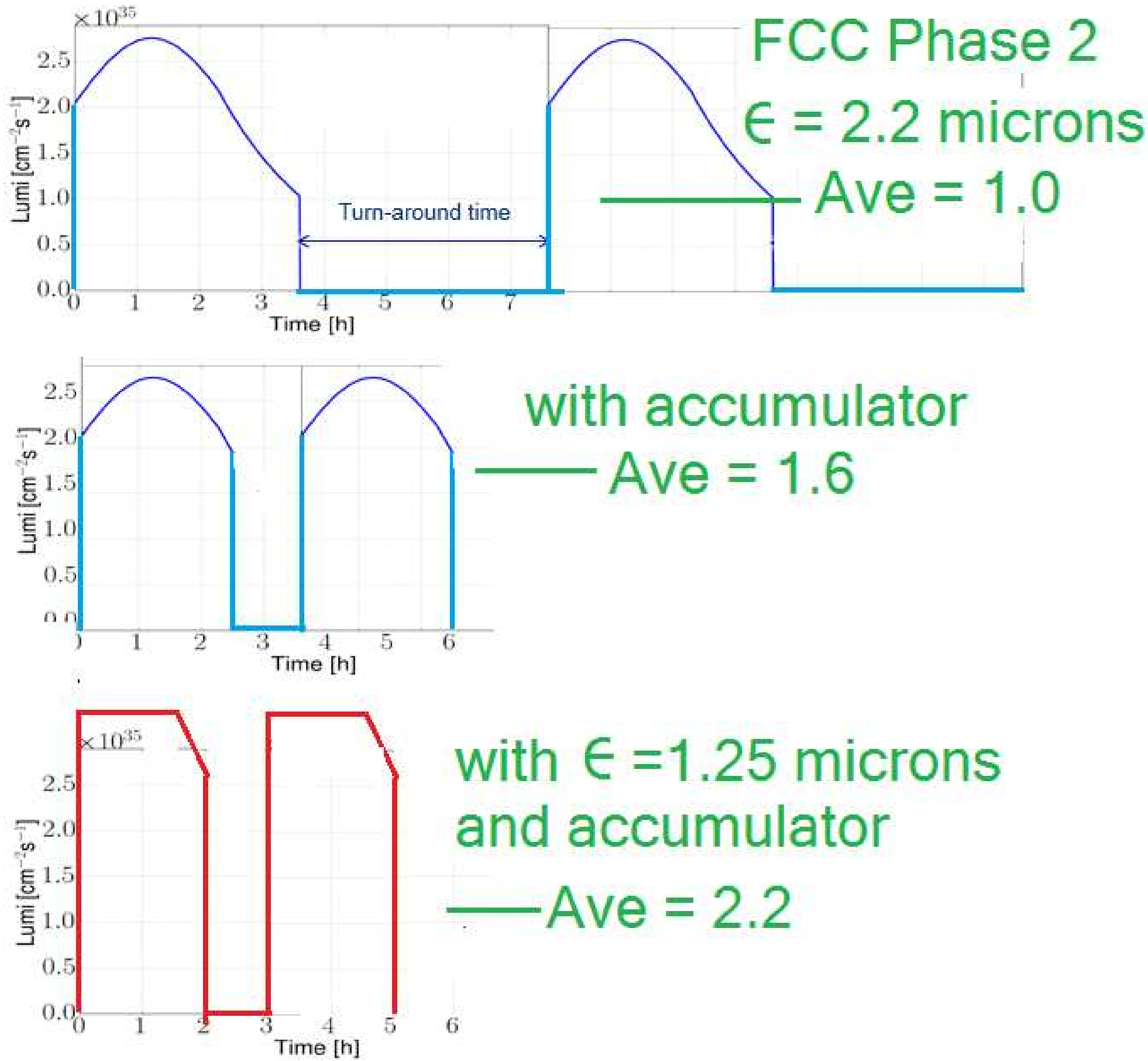
phase 1: β^*=1.1 m, ΔQ_{tot}=0.01, t_{ta}=5 h

phase 2: β^*=0.3 m, ΔQ_{tot}=0.03, t_{ta}=4 h

Well below physics ideal of 5.0 $10^{35} cm^{-2} s^{-1}$

Beyond FCC Phase 2

- Average luminosity is restricted by need for 4-5 hour turn-around time
- But, as proposed, injector train idle for 1/2 the time
- Ave luminosity could be increased by a full circumference, fixed field ($\approx 1T$) permanent magnet accumulator ring
- Filling ring is done ≈ 100 % of time
- Transfer from accumulator to main ring in one turn
- Lost time only needed for ramp up and down ($2 \times$ 20 min. $\approx$ 1 hour
- Space for accumulator should be set aside at start



With a reduction of β^*, Luminosity $\rightarrow\ 5\,10^{35} cm^{-2} s^{-1}$

Interactions/ Bunch Crossing

$$\mathcal{L} \propto \frac{\gamma\ I}{\beta^*} \Delta\nu \qquad I \propto (f\ N_p) \qquad \Delta\nu \propto \left(\frac{N_p}{\epsilon_\perp}\right)$$

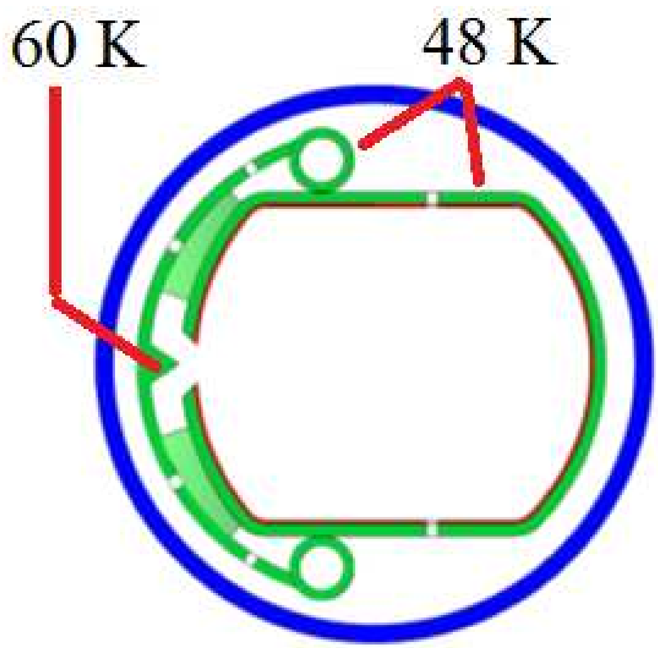
With the luminosity goal of 5 10^{35} cm$^{-2}s^{-1}$ and an LHC like bunch spacing ($\approx 25ns$), the event pile up is excessive ($\approx$ 1700). Only by increasing f by 5 (bunch spacing 5 ns) and decreasing N_p by 1/5 can the pile up be constrained with a fixed current I.

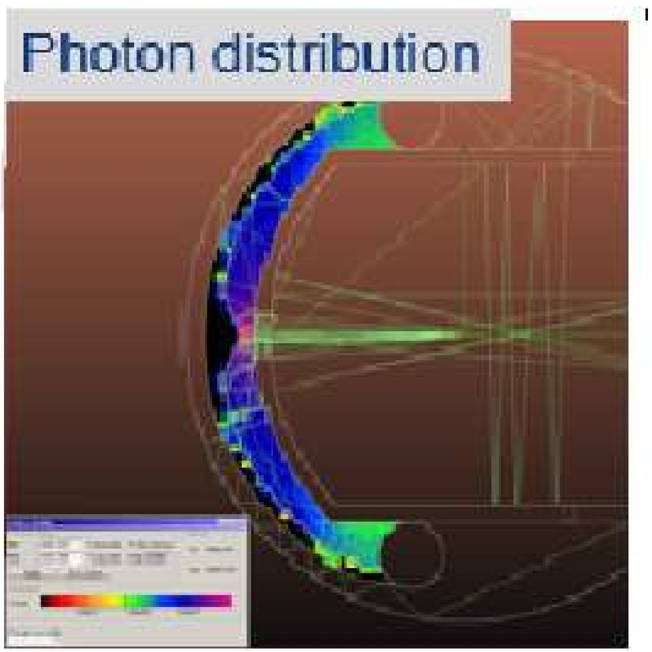
To keep the total luminosity at the goal, we must, and now can, reduce emittance $\epsilon_\perp$ 1.1 $\mu m \rightarrow$ 0.25 μm.

Needs active cooling (as in RHIC) e.g. in accumulator

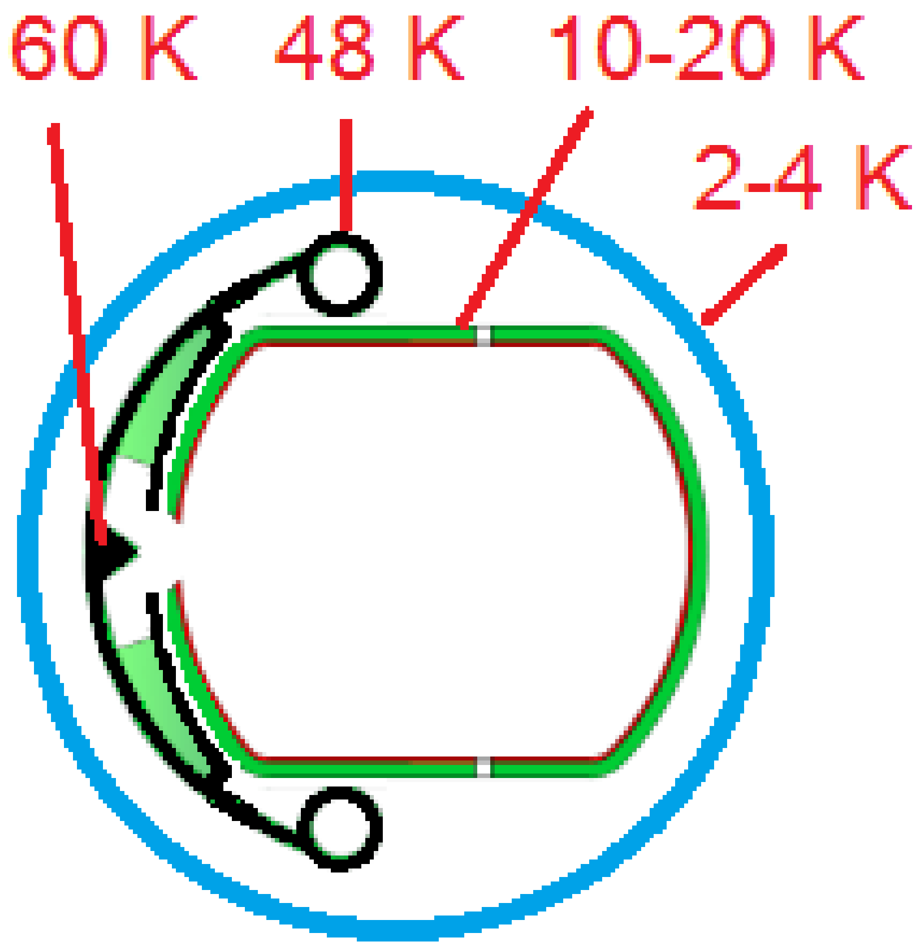
2) SYNCHROTRON RADIATION

- Cryogenic cooling of the dump requires its temperature to be ≥ heating 50 K
- CERN FCC design nicely traps the radiation outside the beam screen
- But having the whole beam screen at 50 K increases the resistive impedance of the copper coating



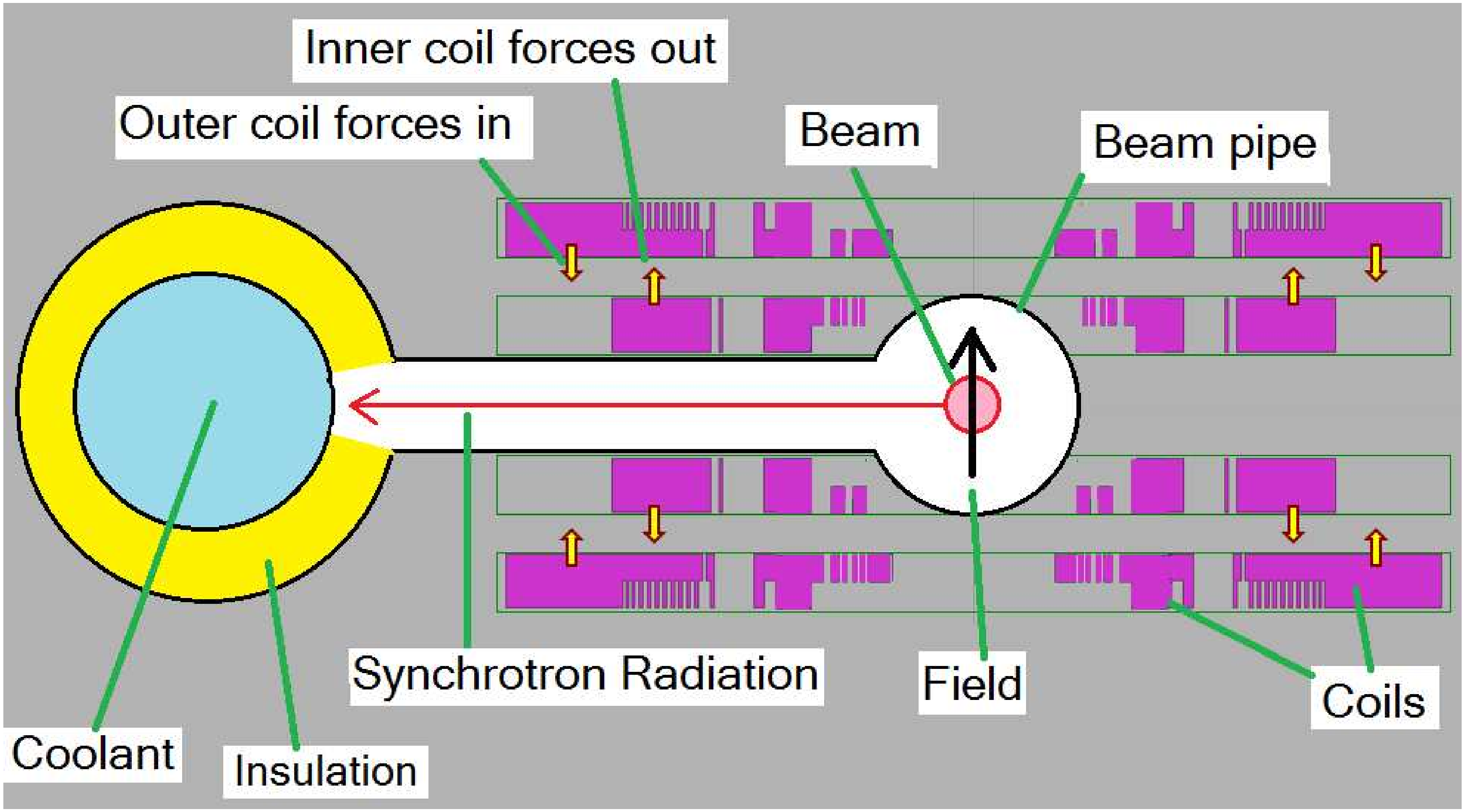


Ideal Screen Design



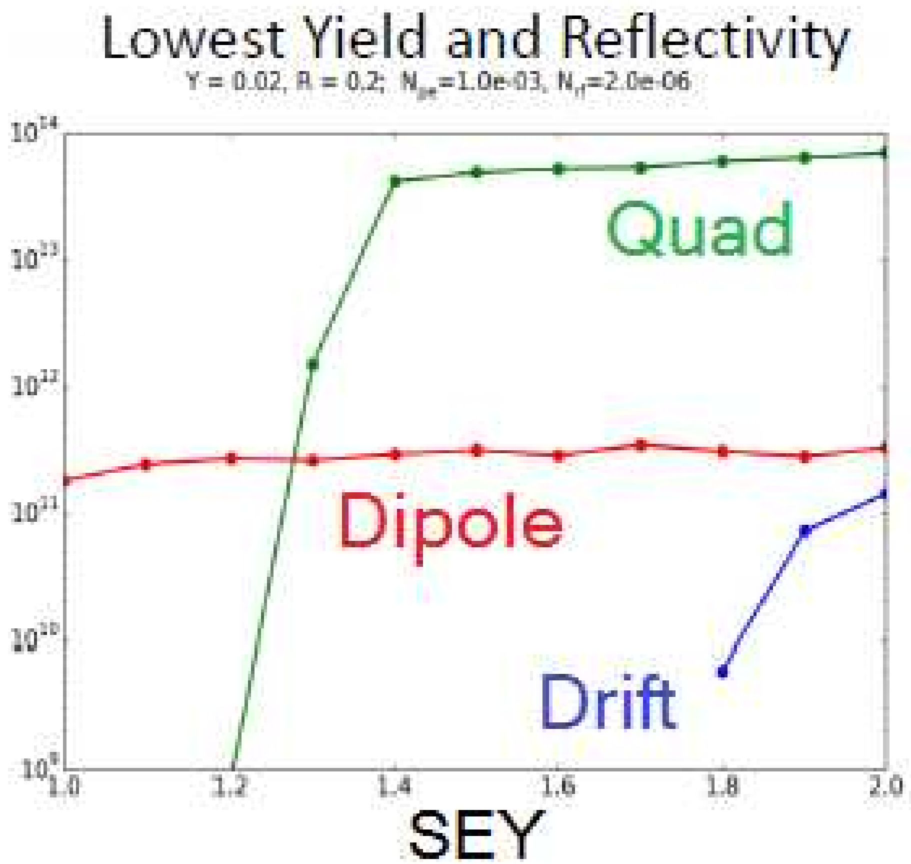
Unfortunately I do not see how to vertically restrain the screen in a quench

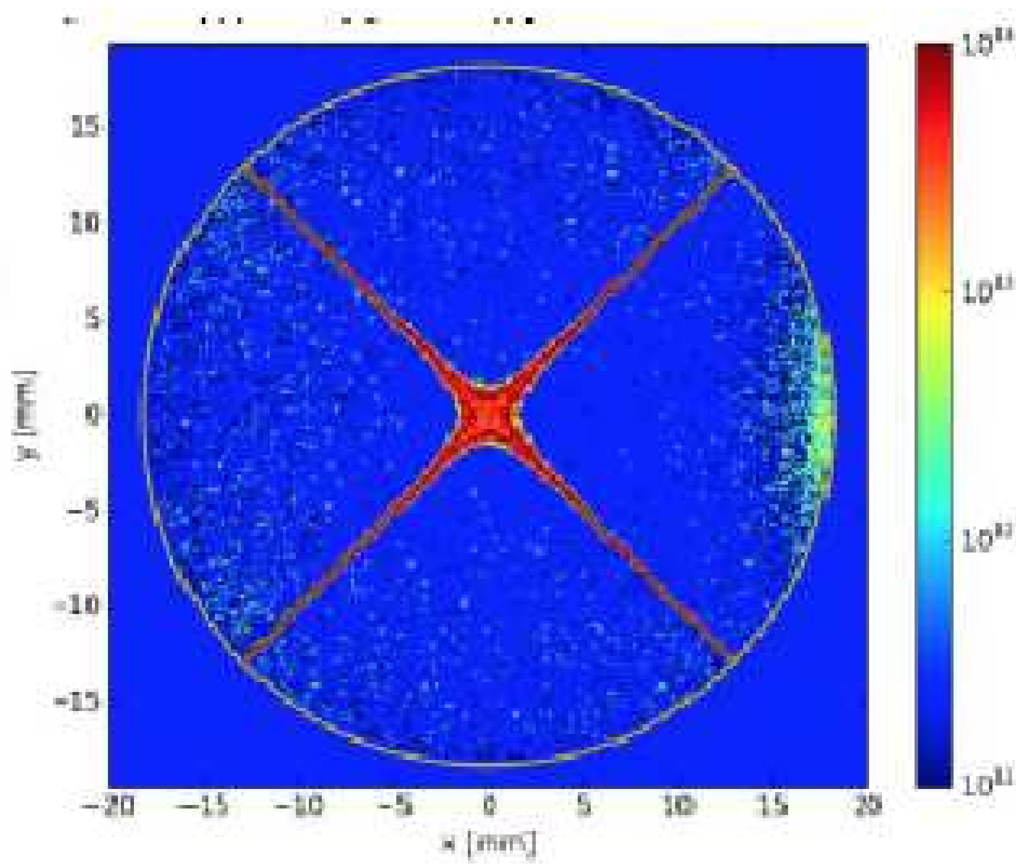
Open Mid-Plane Dipoles



I doubt this is necessary

Synchrotron gen. of e Cloud





- Central density in quadrupoles 2-3 orders of magnitude times that in Dipoles
- Requires Secondary Emission Coefficient < 1.2 : hard

One Proposed solution

Cryogenic Beam Vacuum System Conception

Present and future surface modifications for the mitigation of electron clouds in cryogenic beam vacuum systems

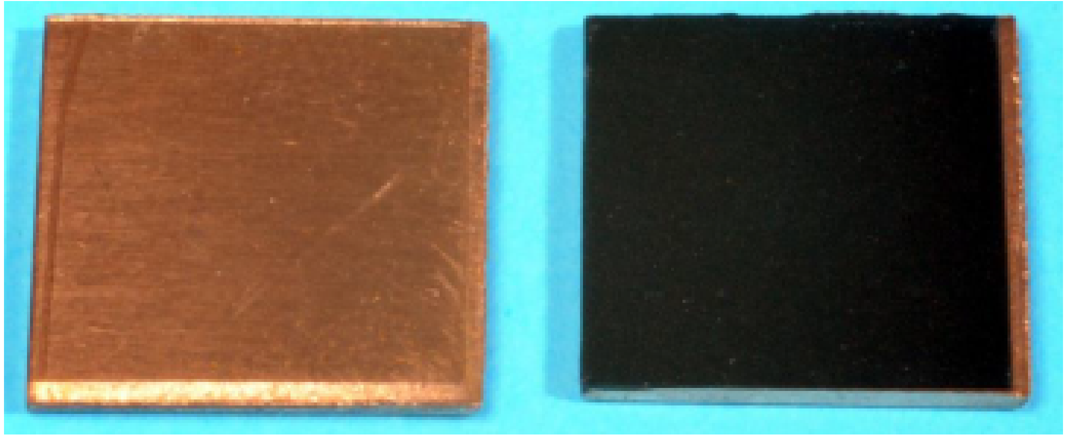
[R. Valizadeh (STFC)]

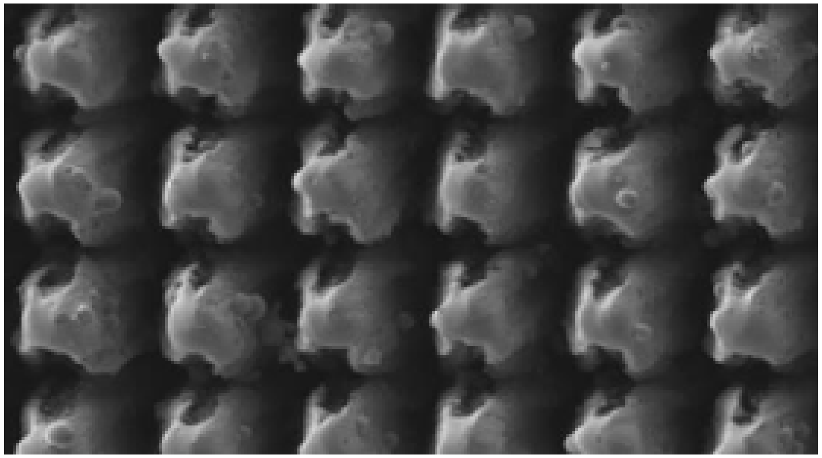
The technique can easily be applied to existing vacuum surfaces where the improvement has to be done *in-situ*.

The blackening process can be carried out in air at atmospheric pressure.

The process is also readily scalable to large areas.

The surface is highly reproducible and offers a very stable surface chemistry which can be influenced during the process.





Another Possible solution

Add a dipole field to the quadrupoles

- Dipole field must only be enough to move zero field location out of the beam tube:
  i.e. A combined function magnet
- If quad coils inside one or more dipole layer, tuning not a problem

CONCLUSIONS

- We have useful expertise
- And many ideas that may be relevant
- Given DoE support, we would like to collaborate

I have included a discussion of Cost vs. Collider Bending Fields, but am not sure if this is of interest when the development of high field technology is a significant motivation

3) Cost vs. Collider Bending Fields

R. B. Palmer, Brett Parker (BNL),
Bill Foster (FNAL/Congress)

BNL Tech Note 317B/25B, 5/1/84 (1984).

Preliminary results presented to R&D Panel

White Paper submitted to R&D Panel

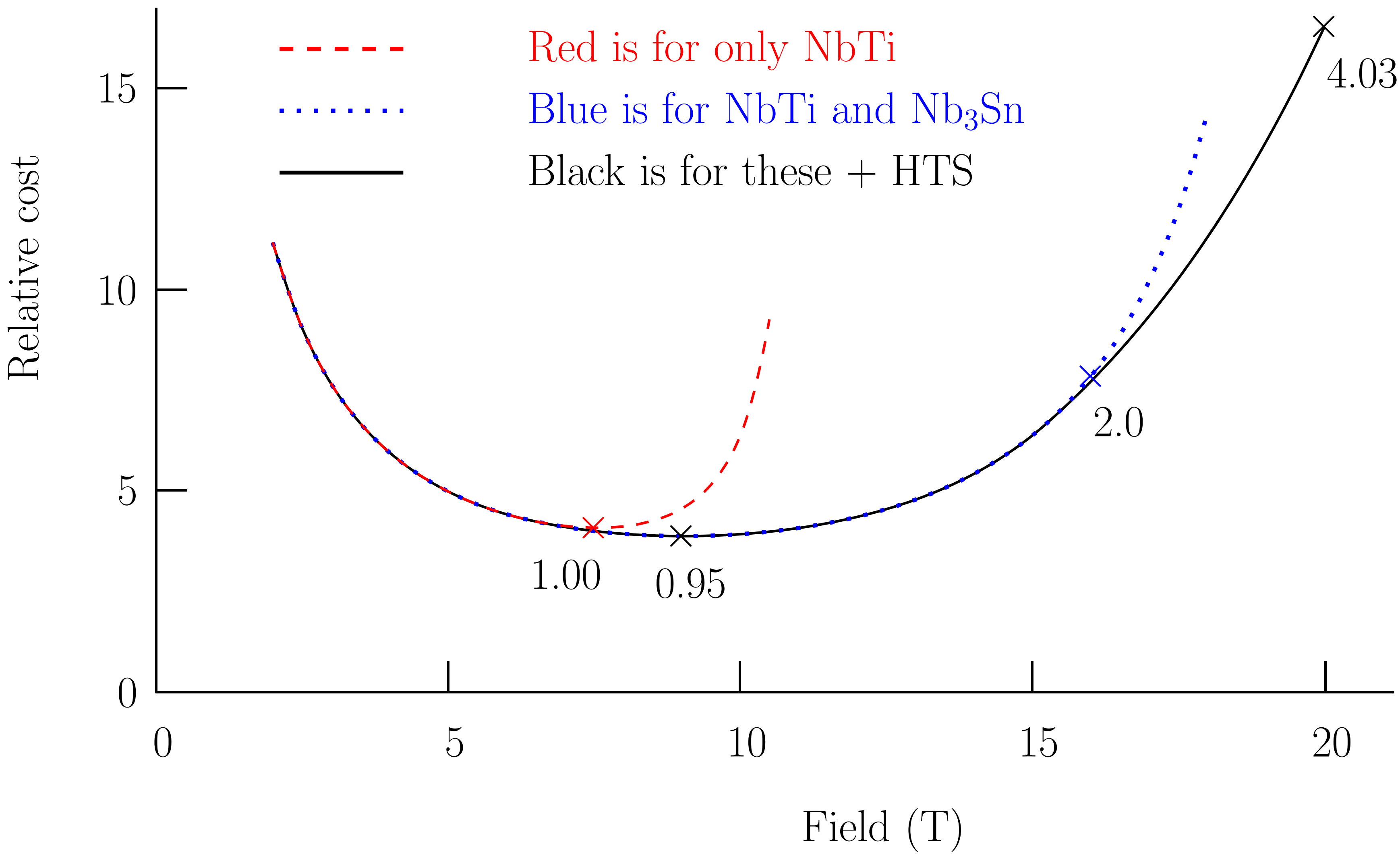
Abstract submitted to IPAC15

Method

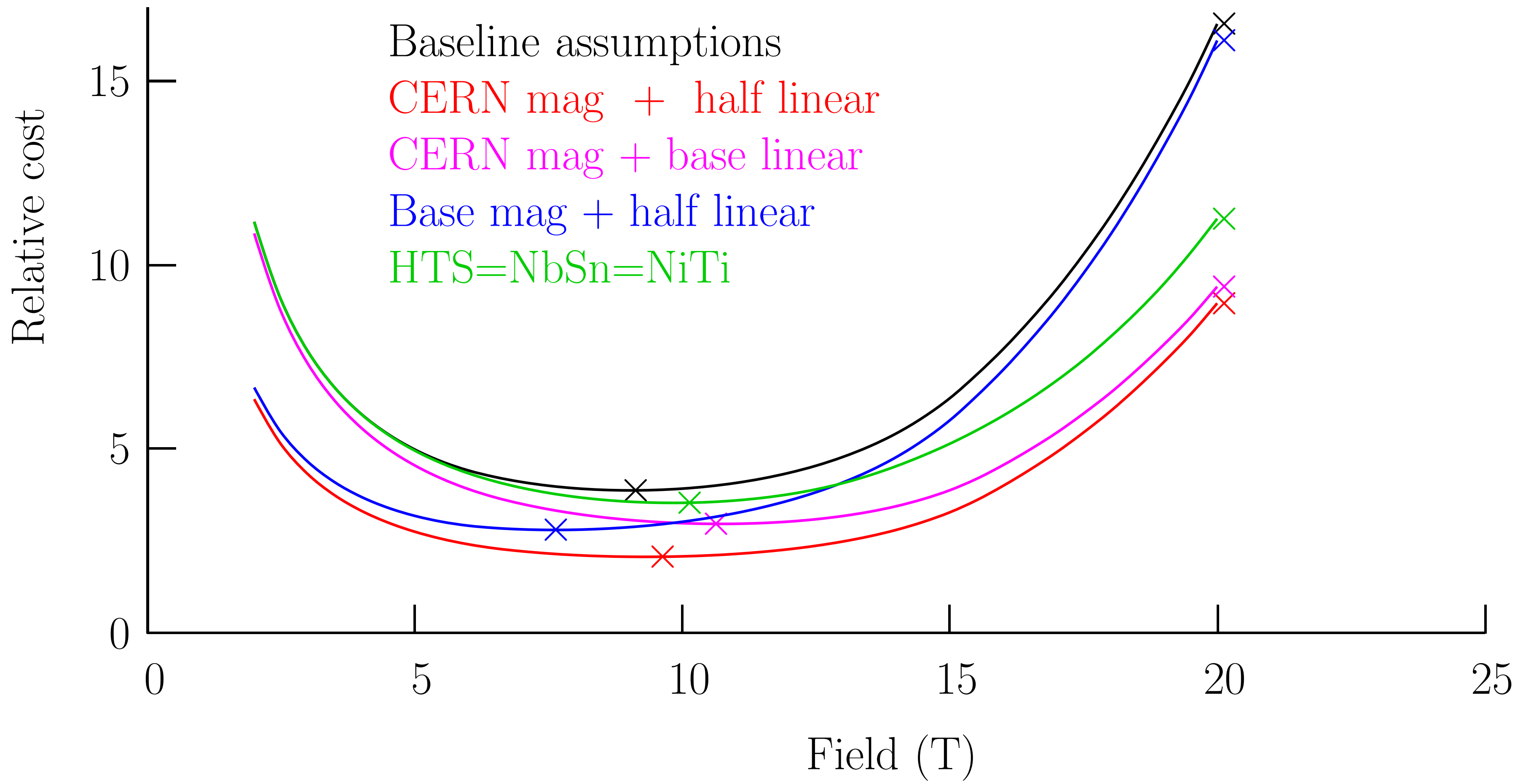
- For different bending fields and different fractions of NbTi, Nb_3Sn, & HTS conductors:
  - Calculate Yoke cross section for minimal saturation
  - Find collar dimensions to hold coil forces
  - Use CERN estimated sc costs and SSC data for support, yoke, cryogenic, and tunnel costs
- Find fractions of conductors to minimize magnet costs
- Determine total magnet and tunnel costs vs. field

At low fields tunnel and other 'linear' costs dominate. At high fields super-conductor and other magnet costs dominate. Between these is a minimum

Costs vs. Bending fields



Sensitivity to Assumptions



CONCLUSION

- This analysis suggests that 20 T is significantly more expensive than ≤ 16 T
- This conclusion does not seem sensitive to the assumptions
- But the result may not be relevant if the development of very high field technology is a significant motivation